



A Nanoradio: Carbon Nanotube Device is Smallest Ever Made

A research group led by Alex Zettl has created the first fully functional radio from a single carbon nanotube. It is, by several orders of magnitude, the smallest radio ever made. In it, the carbon nanotube serves simultaneously as all essential components of a radio - antenna, tunable band-pass filter, amplifier, and demodulator. Successful music and voice reception in the commercially relevant 40-400 MHz range using both frequency and amplitude modulation (FM and AM) was demonstrated.

Carbon nanotubes are hollow tubular macromolecules only a few nanometers (billionths of a meter) in diameter and typically less than a micron in length. Over the last several years, Zettl and his research group have created a remarkable array of devices out of nanotubes including sensors, diodes and a motor.

The idea for the radio arose from the team's work in making exceptionally sensitive force sensors. Nanotubes are like tiny cat whiskers; small forces, on the order of attonewtons, cause them to deflect a significant amount. This incredible sensitivity becomes even greater at the nanotube's flexural resonance frequency, which can be made to fall within the frequencies of radio broadcasts, cell phones and GPS broadcasting.

The new radio consists of an individual carbon nanotube attached to an electrode in close proximity to a counter-electrode. By applying an electrical bias, a negative electrical charge is created on the tip of the nanotube, sensitizing it to oscillating electric fields. Both the electrodes and nanotube are contained in vacuum, in a geometrical configuration similar to that of a conventional vacuum tube.

Although it has the same essential components, the nanotube radio does not work like a conventional radio. It is in part a mechanical device, with the nanotube serving as both antenna and tuner. Incoming radio waves interact with the tube's electrically charged tip, causing it to vibrate. These vibrations are significant only when the frequency of the incoming wave coincides with the nanotube's flexural resonance frequency, which, like a conventional radio, can be tuned by altering the electrical bias which tensions the nanotube. In addition, the nanotube radio produces a field-emission current that is sensitive to the nanotube's mechanical vibrations so that amplification and demodulation of the radio signal is possible. Because carbon nanotubes are so much smaller than the wavelengths of visible light, a transmission electron microscope (TEM) must be used to observe their critical mechanical motion.

To operate the radio, a signal was launched from a nearby transmitting antenna. When the frequencies of the transmitted carrier wave matched the nanotube resonance frequency, reception became possible. An FM radio transmission of the song "Good Vibrations," after being received, filtered, amplified, and demodulated—all by the nanotube radio was further amplified by a current preamplifier and sent to an audio loudspeaker, where it was easily recognizable by listeners. Using a slightly different configuration (without a TEM), the researchers successfully transmitted and received signals across a distance of several meters.

Berkeley Lab's Technology Transfer Department is now seeking industrial partners to further develop and commercialize this technology. Zettl believes that nanoradios will be relatively easy to mass produce. Potential applications, in addition to tiny radio receivers, include a new generation of wireless communication devices and monitors. Nanotube radio technology could prove especially valuable for biological and medical applications. For example, it is possible that the nanotube radio could be implanted in the inner ear as an entirely new and discreet way of receiving information and correcting for impaired hearing.

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